asked Rene Drucker-Colin, vice chancellor of Mexico's Autonomous National University and head of that nation's Academy of Sciences. Whatever the criteria, funders should be prepared for failure, says Michael Meredith of the British Antarctic Survey in Cambridge: "There are going to be times when you don't find anything interesting."

Would-be ocean explorers will also need to convince some developing nations that exploration is in their national interests, says Muthukamatchi Ravindran, head of India's National Institute of Ocean Technology in Chennai. Some, he notes, may be suspicious that richer nations will use exploration as a cover to prospect for exploitable mineral or biological resources, or develop sea-floor maps for military uses. And past failures to share data fully may poison current efforts to gain access to some waters. "Exploration cannot be seen as an invasion [of national waters] with science as the spearhead," warns NOAA's McLean.

One way to defuse tensions, McNutt and others argue, is to make exploration data freely available, ideally in real time. Richer nations could also provide poorer partners with useful products—such as sea-floor maps of national waters—and technologies that would allow homegrown studies. "Technology transfer will be key," says Temel Oguz of the Middle East Technical University in Erdemli, Turkey. "In order to explore, I need new technology."

How to set such sharing rules, however, remains an open question. One idea floated at the meeting was to establish a formal committee under the auspices of the United Nations to set priorities and perhaps funnel funding. Such a high-level body, said Marta Estrada of Spain's Ocean Sciences Institute in Barcelona, would "help researchers leverage extra funds from their own governments." There was also support for a less bureaucratic arrangement, with nations and institutions cooperating as their interests overlap. Others argued against any structure that would complicate existing efforts to negotiate the sharing of ship, satellite, and submarine time.

Researchers had plenty of suggestions for exploration priorities. Many agreed that mapping of unknown areas—currently 90% or more of the ocean—will be essential. "You can't separate mapping from exploration—it's where you start," says Larry Mayer of the University of New Hampshire, Durham, who showed off cybermapping tools that allow users to "fly" through three-dimensional seascapes. There was also strong support for targeting the 20-million-km^2 Southern Ocean. "It has a pretty good claim to being the least explored place on Earth," says Meredith.

Some biologists, meanwhile, argued for going deep and getting small. "In general, the deeper we go the less we know—and the bigger the animal, the more we know," said Annelies Pierrot-Bults of the University of Amsterdam. Others emphasized the need to augment the "snapshots" taken by traditional exploration missions with long-term monitoring data collected by satellite and buoy systems.

The job of sifting through and organizing these ideas now falls to the 15-member academy panel, led by marine seismologist John Orcutt of the Scripps Institution of Oceanography in La Jolla, California. It hopes to weigh in on these and other issues—such as whether the U.S. should build a dedicated exploration vessel—by the end of the year, with a public report due in February 2003. That would allow the panel to feed into a major U.S. government report on ocean issues due next year, as well as ongoing European efforts to craft a new ocean research agenda.

Meanwhile, New Zealand scientists are settling down to analyze the reams of data from their recent expedition. One of the first tasks, says Wright, "will be to give appropriate names" to the newly discovered mountains. Ocean exploration advocates hope that such mass-naming exercises soon become commonplace. **–DAVID MALAKOFF**

CREDIT: NASA

SPACE STATION

Can Space Station Science Be Fixed?

A blue-ribbon panel reporting next month has the task of setting U.S. station research priorities. But will anyone listen?

If U.S. space station research were a child, it would be in foster care. For the past decade, it has been a victim of unrealistic expectations, abuse, and neglect. Politicians touted fanciful space-derived cures to justify spending billions of dollars to build the station, outside researchers disparaged the effort as worthless, and NASA managers blatantly "borrowed" its allowance.

In limbo. The space station is flying, but its science mission remains largely earthbound.

But these three groups—lawmakers, agency officials, and the scientific community—now say it's time for a realistic and credible research plan to give the much-maligned program a shot at a stable adolescence. Next month, a star-studded, 20-member scientific panel appointed by NASA Administrator Sean O'Keefe will propose a firm list of priorities for research aboard the orbiting lab now under construction. To be effective, the panel must make a case convincing enough to win the backing of a cash-strapped NASA, a parochial Congress, and a fed-up research community—a tall order.

The timing may be right, however. A new team of NASA managers is onboard, lawmakers are growing anxious, and the broader science community is becoming involved through the panel, chaired by Columbia University endocrinologist Rae Silver. This makes it an auspicious moment to fix a host of internal and external troubles plaguing the biological and physical research program at NASA, which is centered on the space station. Those troubles include chronic shortages—of money, flight opportunities, research equipment, scientific rigor, and respect—and an excess of disciplinary rivalry. "This is the time to change the system," says Joan Vernikos, former head of NASA life sciences.

One of the panel's toughest tasks may be to overcome entrenched skepticism among researchers, who have seen many previous recommendations come to naught. "We've revisited the same problem for the past 10 years," says Martin Fettman, a veterinarian at Colorado State University in Fort Collins and longtime space researcher who declined to serve on Silver's panel. "I'm tired of participating on committees whose reports collect dust."

Weighty advice

Silver acknowledges that her panel—which bears the unwieldy name of the Research Maximization and Prioritization Task

Force—is a Johnny-come-lately. Before plunging in, she gathered 24 kilograms of studies and reports by NASA and advisory panels of the National Research Council (NRC), weighing them on her bathroom scale. "Some areas of research have been reviewed repeatedly for 15 years," she notes.

But no panel before hers has had the charter to pick priorities across a broad array of areas, from how cells grow in microgravity to the creation of new drugs. It is looking at eight different fields, including fundamental biology and physics, biomedical research, biotechnology, combustion science, fluid physics, materials science, and space product development. O'Keefe says he is looking for the highest possible scientific payoff. "We want to use [the station] for a purpose, not for a photo op," he told reporters last month. And he insists that he doesn't want the panel to feel bound by any constraints.

The panel does, however, face one major hurdle: time. Due to report in mid-June, it has had less than 6 weeks and only three meetings lasting 2 days each to do its work. Task force members have done a "meta-analysis" of earlier studies and now are laying out overall priorities, Silver said last week at the final meeting.

Given the time constraints and the breadth of the panel's task, some researchers are skeptical about the outcome. Critics note that many members are distinguished but are largely unfamiliar with station research. "This is not their area of expertise," grouses one station researcher. Others worry that the preponderance of biologists on the panel will mean that discipline takes precedence over less glamorous areas. "Biology should play an important role but not to the exclusion of physics," says David Weitz, a Harvard University physicist who recently conducted experiments on the physics of colloids in space.

Silver notes that her panel's job—which she says is being accomplished largely by e-mail to accommodate the busy schedules of members—is simply to come up with the best research plan. Given the intense concern on Capitol Hill that the station investment might yield little science, O'Keefe will be under pressure to abide by the panel's priorities. But scientists such as Fettman are only too aware that earlier studies have been ignored.

Heavy lifting. Columbia's Rae Silver weighs previous station reports.

Broken promises

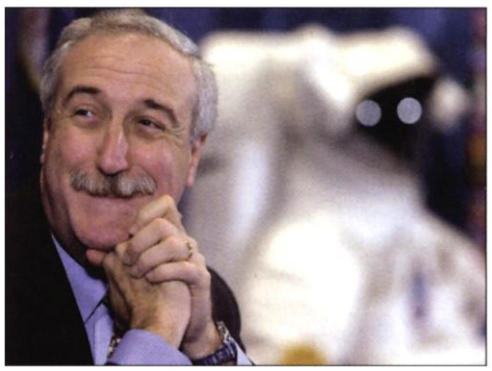
The research community's skepticism stems from a long history of broken promises. Although the space station has largely been justified by NASA managers and politicians for its science potential, the actual research program has consistently taken a back seat. During the late 1990s, for example, NASA managers diverted nearly $1 billion that was intended to build scientific facilities to plug gaps in funding for basic construction of the station.

Matters came to a head last year, when mounting cost overruns forced the agency to halt work on station elements that would enable the number of crew members to double from the current three to the planned six astronauts. Because NASA estimates that 2.5 people are needed to maintain the facility, crew members would have little time to conduct research. Scientists such as Fettman cried foul, Congress complained, and European, Japanese, and Canadian partners formally told the U.S. government that such cuts were unacceptable.

O'Keefe, a station critic in his previous job as deputy at the White House Office of Management and Budget, was unmoved. He insisted that the number-one priority is to bring station costs under control. The Silver panel is intended to assure the scientific community, international partners, and Congress that research still matters—even in this time of belt-tightening.

Scientists hoping to conduct experiments in the microgravity of low-Earth orbit welcome the assurance but say they are tired of waiting for the promise of the space station to become reality. Flying an experiment on the space shuttle or the Russian space station Mir during the 1990s was typically an ordeal requiring years of patience, reams of paperwork—and the realization that they might not be able to do it twice. "No one in their right mind expects results from one experiment," says Vernikos. The station was expected to solve problems of limited slots, long waits, and short flights.

Those hopes keep receding, however. Take the case of the station's centrifuge. Innumerable



Big payoff. NASA's Sean O'Keefe wants a revamped research effort.

NASA advisers have urged the agency to make a large centrifuge a central and early part of the research effort. By providing a range of gravitational levels, a centrifuge could supply vast amounts of new data on the effect of gravity on plant and animal development. Work would range from physiological studies on mice to biotechnology applications. But it has repeatedly been put on hold. In the mid-1990s, NASA turned over responsibility for the centrifuge to Japan in exchange for launching Japan's research module on the space shuttle. Now the centrifuge—a decade ago slated to go up this year—is not scheduled for launch until 2007.

George Sarver, who heads the station's biological research project at NASA Ames Research Center in Mountain View, California, admits that the delay is "frustrating for everyone." But, he says, at this stage no amount of money could prepare major facilities like the centrifuge much before 2007. Others add that with a crew of three, research would still get short shrift.

NASA's new biology and physical sciences chief, Mary Kicza, puts the best face on that harsh reality. She notes that a July shuttle mission will be devoted to research and that a host of experiments—from biomedical studies of astronauts to fundamental physics—are well under way. But crew time is limited, the shuttle flight is the last of its kind planned, and other options—such as Mir—don't exist.

Most ominously, researchers are giving up. "On a percentage basis, the number of [space] researchers is going down at a fairly impressive clip," notes Ursula Goodenough, a biologist at Washington University in St. Louis and a longtime skeptic of space-based research. Task force member Mary Jane Osborn, a biologist at the University of Connecticut, Farmington, adds that "if there are long delays, obviously the community will evaporate." Even former astronauts who have successfully flown experiments say they have had enough. "We're balancing on the edge of a razor all the time," says Millie

CREDITS: (TOP TO BOTTOM) TONY DEJAK/AP; ILIA KARATSOREOS

Hughes-Fulford, a biochemist at San Francisco's Veterans Administration Medical Center, who has focused on gene expression in microgravity—and is one of the few scientists to have done a whole series of experiments. "People like me are saying, 'Maybe I should do NIH [National Institutes of Health] [grants] instead.'"

Silver lining?

Such fatalism will be difficult for the Silver panel to counter. But researchers say the task force has the power to define the coming debate over station science. The hardest part will be to lay out priorities. Kicza's office has traditionally tried to slice its disciplinary pie in an equitable manner. But that makes little sense now, given budget and flight constraints. Says Vernikos: "We're not NIH or NSF [National Science Foundation]—and we never will be. We should focus on very specific problems."

But there may be ways to do more with less. Automation may ease the problem of crew time. The European Space Agency already has taken a lead in developing equipment that requires minimal attention in orbit. Hughes-Fulford's latest experiment, for example, will make use of the European Biopack, a largely automated centrifuge, slated to fly in July on the shuttle. Ames's Sarver says NASA is pushing automation to reduce the need for scarce crew time. For example, a $35 million cell-culture unit slated to fly by 2006 will take samples and preserve and refrigerate them without astronaut help, and a built-in microscope will enable researchers on the ground to have more control over the experiment. But automation can create more costs and problems—for instance, by greatly increasing the need for space-consuming freezers to store samples, notes Tim Hammond, a biologist at Tulane University in New Orleans.

If an independent research organization, perhaps modeled on the Space Telescope Science Institute in Baltimore, Maryland, were established, it might also provide better direction with less bureaucracy for station science. An NRC panel already has suggested that course, but the proposal has bogged down at NASA. Some congressional members who support Houston's Johnson Space Center fear it could usurp that organization's control over station operations, and others worry that an independent institute would have less political pull in winning an annual budget. Kicza has a team studying whether the agency should back the idea.

Increasing the amount of crew and research time in orbit would obviously be the best solution for station users. One proposal is to attach the space shuttle to the station for long periods, providing room for a much larger station crew. The shuttle could also be flown on an annual mission dedicated wholly to science, as in the one slated for July. Both ideas would require much more money than O'Keefe has on the books. And Congress, despite its concern over the health of station research, may prove extremely reluctant to fork out more money for an effort already mired in red ink.

That reality is what makes researchers such as Fettman skeptical that NASA will accept Silver's recommendations any more readily than it has her predecessors'. The problem, he says, is not with the research program. "What needs changing," he says, "is NASA's response. If they listened, wouldn't that be too cool?"

Still, many researchers say the panel can get the ball rolling by carefully spelling out what needs doing immediately and what can wait. Recommendations for more automation, greater use of the shuttle for crew and experiments, and a limited research repertoire—along with more money—will help, they add. That will involve pain for those researchers left behind at the launch pad, but it might give the program with an unhappy childhood a shot at maturity.

–ANDREW LAWLER

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MATHEMATICS

NSF Moves With VIGRE to Force Changes in Academia

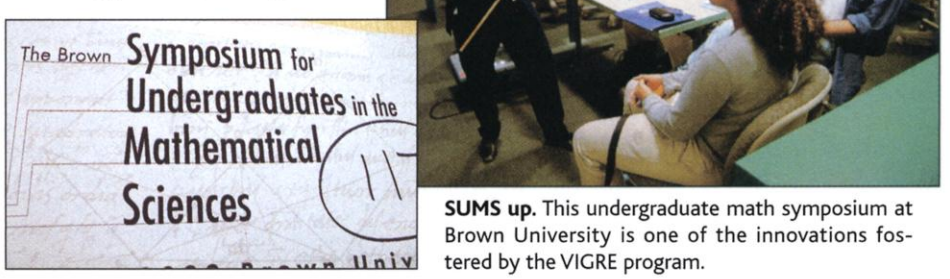
A new NSF program aims to make mathematics more user friendly for students—but it's not for every university department

Three years ago, the National Science Foundation (NSF) set out to change how the United States trains its mathematicians. This spring, it sent a handful of universities their first report cards. The verdict: The culture of math departments is changing, but even the most prestigious departments will find themselves out in the cold if they don't do it NSF's way.

The vehicle for change is an ambitious system of grants designed to fix a badly leaking educational pipeline. From 1992 to 1999, the number of U.S. mathematics majors dropped by 23%, and the number of math graduate students fell by 20%. When those students emerged with diplomas, many could not find jobs. In 1995 and 1996, the unemployment rate among new math Ph.D.s topped 10%, rivaling that of Michigan steelworkers. Many graduate students postponed entering the job market, causing the median "time-to-degree" to rise to nearly 7 years—two more than most math departments consider optimal.

In 1998, a blue-ribbon panel chaired by retired General William Odom concluded that the talent drain was threatening not only the nation's leading position in mathematics worldwide but also its ability to innovate in related disciplines. In response, NSF launched its Grants for Vertical Integration of Research and Education (VIGRE) program. The program has become a showpiece in NSF's most rapidly growing division, which hopes to boost VIGRE's budget next year by 62%, to $26 million.

VIGRE is based on the assumption that declining enrollments were caused by a lack of mentoring, according to Don Lewis, who as head of the math division created the VIGRE program. "Students viewed mathematics courses only as training for mathematics teaching," he says. Fields such as genomics, cryptology, and image processing were awash in jobs ideal for trained mathematicians, he adds, but students and postdocs didn't know about them. The answer, to Lewis, was obvious: Help universities do a better job of training and informing students about nontraditional careers. Or, as Bill



SUMS up. This undergraduate math symposium at Brown University is one of the innovations fostered by the VIGRE program.